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TEXT ORGANIZATION AND COMPREHENSIBILITY IN TECHNICAL WRITING

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Contracting Officer's Representative
Judith Orasanu

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Technical texts often introduce scientific principles by deriving the principle prior to stating it. This "proof-first" organization violates writing guidelines suggested by current text learning theories. The current research compares the effect on comprehension of this type of structure with its logical alternative a "principle first" structure. Results indicate that readers spend more time with information when it occurs first.

Thus, the principle-first structure focuses attention on the principle, and the proof-first structure (not surprisingly) focuses attention on   (OVER)

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20. Abstract (continued)

the proof.
  Additionally, readers find it easier to predict what is important in
principle-first texts, and used the principle-first approach more often in
summarizing. These findings indicate that readers find the information in
a principle-first organization easier to process and store. Ongoing research
is investigating differences in what readers learn using these two structures.

Text Organization and Comprehensibility in Technical Writing
Executive Summary

A major focus of much technical writing is the teaching of scientific and mathematical principles. These general principles are important because they are critical for understanding and solving many real-world problems. There are two ways in which this type of content is typically presented in a text: (1) the principle is stated and then *proven* for the reader (a "principle-first" structure), or (2) the principle is proven first without stating the principle until after the proof is completed (a "proof-first" structure). The current ongoing research is investigating how these two alternative organizations influence the comprehensibility of technical texts.

In two completed studies, we examined how these two text structures influence the types of information readers attend to during reading, and the ease with which they are able to determine what is important in the text. There were several important findings. First, readers spent more time on the information that occurred first in the passage. Readers spent more time on the principle in "principle-first" passages and more time on the proof in "proof-first" passages. This indicates that these two structures produce differences in the amount of attention given to the principle and proof information. Second, readers were better able to determine what was important when the information was *organized according to a principle-first structure.* This indicates that the principle-first structure is more deterministic and therefore easier to process because there is less uncertainty as to what the important points are in the passage. Third, readers summarizing passages tended to always use a principle-first structure, regardless of the original passage structure. Readers would reorganize proof-first passages into a principle-first structure. This indicates that the principle-first structure is the preferred structure, and suggests that readers may find this structure easier to store and recall.

In conclusion, research completed thus far indicates that a principle-first structure is easier to process and focuses more attention on the important information (i.e., the principle) as compared to the proof-first structure. This suggests that this structure would be most appropriate if the primary learning goal is for the reader to learn the principle. However, it *is possible that the proof-first structure could produce better learning of the proof* content. This is because this structure focuses attention on the proof, and also makes it more difficult for the reader to determine what is important. The reader may therefore process the text more thoroughly overall, rather than focusing specifically on the principle. Research in progress is examining differences produced by these structures in the learning of the principle and proof content.

Abstract

Technical texts often introduce scientific principles by deriving the principle prior to stating the principle itself. This "proof-first" organization violates writing guidelines suggested by current text learning theories. The current research compared the effects on comprehension of this type of structure with its logical alternative, a "principle-first" structure. Results indicate that readers spend more time on information when it occurs first. Thus the principle-first structure focuses attention on the principle and the proof-first structure focuses attention on the proof. Additionally, readers found it easier to predict what was important in principle-first texts, and used the principle-first structure more often in summarizing. These findings suggest that readers find a principle-first organization easier to process and store. Ongoing research is investigating differences in what readers learn with these two structures.

Text Organization and Comprehensibility in Technical Writing

Theories of text comprehension have suggested guidelines for organizing texts in order to facilitate comprehension and learning. These guidelines generally involve providing the reader with information that can be used to interpret, organize, and anticipate the text content, thus making the text more predictable. This can be done, for example, by giving the reader advance organizers (Ausubel), signaling or highlighting the text organization (Meyer), following standard writing conventions (Kieras), and using conventional rhetorical structures familiar to the reader (schema theory).

The current research examined the effects on comprehension of a conventional organizational structure which is common in scientific texts, but which does not follow the general recommendations suggested by current comprehension theories. This is an organizational scheme in which a scientific principle is derived for the reader prior to presenting the principle itself (referred to as a "proof-first" structure). In both science and math texts, it is common for the text to present the reader with a hypothetical situation and proceed to derive a principle or rule using the elements in that situation without stating the principle itself. Thus the reader does not know what the goal of the proof is until the end of the proof. The logical alternative to this structure is a "principle-first" organization. In this structure the text segment begins with the statement of a principle, and then a derivation of the principle is presented.

Although both of these structures are common in scientific texts, they would be expected to have different effects on comprehension. Specifically, the proof-first organization violates many of the guidelines for writing suggested by current text learning research. First, the reader is not provided with a conceptual background, or advance organizer, for interpreting and organizing the proof as they read, making it more difficult to pick out the important information. With the principle-first organization, the reader knows what is being proven, and hence can interpret the proof information as it relates to the principle. Second,

the proof-first structure does not conform to the writing convention of placing the important content close to the beginning of the text, so this content is not where the reader expects it to be. The principle-first organization follows this writing convention. Third, the proof-first structure is specific to particular domains (mathematical and scientific), so novice readers in these domains would not have well-developed schemas for this type of structure. They therefore would not necessarily expect that a principle would follow the proof and would be unsure of the overall text structure. The principle-first organization is more readily detectable and familiar, and novice readers would most likely have a structural schema for this format that they could use to organize and anticipate information as they read.

Accordingly, the proof-first structure would be expected to be more difficult for novices to process because they would have difficulty determining the overall text structure and what the important content was during reading. The two studies reported here contrasted the principle-first and proof-first organizations in terms of their ease of comprehension for novice readers. In the first study, scientific novices read physics texts presented in these two formats while their reading times were recorded. Afterwards they wrote brief summaries of the passages. Reading times were examined to see if readers found one organization easier to process overall, and if they attended to different types of information when reading these two structures. The summaries were analyzed to determine whether readers tended to maintain the original passage organizations, or if they reorganized the text according to a preferred structure. In the second study, novices rated the importance of sentences in texts with these two structures as they were reading the passages (i.e., rating each sentence before reading the next sentence). After completing the entire passage, readers were allowed to go back through the passage and revise their ratings. The goal of this study was to determine whether readers found it easier to predict what the important content was as they were reading with one of these text structures.

Experiment 1

This study examined differences in reading times and summaries of information presented in a proof-first and principle-first structure.

Method

Materials. Four target passages were used, each containing a principle segment (about 3 sentences in length) and a proof segment (about 10 sentences in length). These passages were written so that the two main segments were interchangeable; that is, the proof or the principle could be presented first. A proof-first and principle-first version of each passage was used in the study. Analyses of subjects' familiarity ratings for these passages were collected as part of the experiment. These ratings indicated that one passage was too familiar to the subjects to include in the study. Therefore, the data for this passage were excluded from the reading time and summary analyses.

Subjects. The subjects were 24 undergraduates who had completed no more than 1 semester of college-level physics.

Procedure. The study was conducted in 2 sessions. In each session subjects read 2 practice passages and 2 target passages. The order of presentation of the practice passages was kept constant and the order of the target passages was counterbalanced. Each session alternated practice and target passages, beginning with a practice passage. The passages were presented on a VDT one sentence at a time. Subjects pressed a button to change the sentence that was being displayed.

Subjects were told that they would be reading short passages about physics and writing an 8-12 sentence summary of each. The summaries were to contain what they considered to be the main points of each passage.

Results

The reading times were analyzed with a multiple regression including as variables the experimental session (first/second), passage version (principle-first/proof-first), sentence type (principle sentence/proof sentence) number of words, passage, and the type x version interaction. Results indicated that all effects were significant with the exception of the main effect of version. The type x version interaction is shown in Figure 1. It indicates that readers spend more time on the same text content when it is presented at the beginning of the passage. The principle-first organization results in more time spent on principle information and the proof-first structure produces longer reading times for the proof. This suggests that the two text structures differ in the amount of attention that is focussed on the principle and proof segments during reading.

The summaries were scored according to whether they maintained the original passage structure or reversed the proof-principle order. The analysis indicated that there was a much greater tendency to reverse the order of the content when it had been presented in a proof-first structure. With the principle-first structure, only 1 subject adopted a proof-first structure in their summary (29 maintained the original structure). With the proof-first structure, 25 subjects used a principle-first structure in summarizing (5 maintained the original structure). A chi-square on these frequency counts was highly significant ($X^2 = 39.10$, $p < .001$). This suggests that readers find the principle-first structure more "natural" in that they use this structure even when summarizing proof-first texts.

Experiment 2

This study examined differences in the ability of readers to predict the importance of information as they read texts organized according to a proof-first or principle-first structure.

Method

Materials. Two of the three passages used in Experiment 1 were used in Experiment 2. Some minor revisions were made in these two passages to reduce the overlap between the main principle statement and the end statement of the proof. The passages were printed one line on a page so the subjects could rate the importance of each sentence prior to viewing the information following that sentence.

Subjects. The subjects were 20 undergraduates who had completed no more than 2 semesters of college-level physics.

Procedure. The subjects were told that this study examined how people go about determining what is important as they read. They were told that they would read several passages presented one sentence at a time and rate the importance of each sentence as they read. They were to use a 5-point scale, 1 being most important (i.e., a main point of the passage) and 5 being least important (i.e., information unrelated to the main points of the passage). After they had completed the ratings for the four passages, they were told that they should go back through the two target passages and revise the ratings based on their knowledge of the complete passage.

Results

The ratings for the principle segment and proof segment of the text were analyzed with a multiway frequency analysis with type (proof/principle), passage, version (proof-first/principle-first), and rating (original/revised) as factors. The analysis indicated significant type x version and type x passage interactions. Because there was not a significant difference between the original ratings and their revisions, the analysis was rerun on just the original ratings. Results again indicated significant type x version and type x passage interactions. The finding of interest, the type x version interaction, is shown in Figure 2. As can be seen, readers tended to rate the same content higher in importance when it was

presented at the beginning of the passage Both the principle segment and the proof segment were considered to be more important when they occurred first. This is consistent with research indicating that readers tend to expect the important information to occur early in a text.

The number of revisions made in the importance ratings were analyzed with a logistic regression including the variables of type, passage, and version. The analysis indicated a significant type x version interaction in the number of ratings changed. This interaction is shown in Figure 3. A greater proportion of sentence ratings were changed when the text segment was presented first in the passage This indicates that there is greater uncertainty as to the importance of information when it occurs early in the passage. Additionally, the main effect of version shows that more changes were made overall when the proof statement occurred first This indicates that the principle-first structure is more deterministic than a proof-first structure in that readers are better able to predict the relative importance of sentences organized in this manner.

Discussion

This research contrasted two text organizations used in introducing and explaining principles -- a principle-first and proof-first structure. The results indicated differences in both the attention given to principle and proof content, and the overall comprehensibility of the texts.

Readers spent more time on text content when it was placed at the beginning of the text. They spent more time on the principle with the principle-first structure as compared to the proof-first structure. The opposite was true for the proof, with readers spending more time on this content with the proof-first texts. This suggests that information receives more thorough processing when it occurs at the beginning of a text. This processing difference could result from two sources

First, the extra processing time may be a result of particular comprehension processes that occur when a reader begins a new text and must establish an initial internal text base. These processes include selecting or developing an appropriate *schematic framework*, accessing relevant prior knowledge, encoding new concepts in the initial representation, etc. Once an initial framework has been developed and text referents encoded, fewer and fewer new concepts are encountered as the reader progresses through the text. Thus the farther the reader is in the text, the more likely it is that the construction of the internal text representation will involve adding information to an existing structure, rather than the more time-consuming process of generating new structure. Therefore, the reader spends more time on the text segment occurring first because this segment contains more new concepts relative to the content occurring later in the text. This is most likely the source of general serial position effects in reading times, and would also contribute to the passage organization effects found in this study.

Second, this extra processing may reflect an assumption on the part of the reader that the information presented first is particularly important, and hence should receive more attention. Research by Kieras has shown that readers use "initial mention" as an indicator of importance, and expect important content to occur at the beginning of a text. This was also indicated by the importance ratings in the current study. Readers rated the principle and derivation higher in importance when they were presented first, indicating that they anticipated that this content would be important. Thus the placement of the principle or proof at the beginning of the text in effect emphasizes that content to the reader. This suggests that this content may be better learned when presented first because the reader assumes it is important and therefore devotes more effort to understanding it. These attentional differences may therefore result in differences in learning as well. Thus the principle-first structure may produce better learning of the principle because it emphasizes this content; the proof-first structure may result in better learning of the proof.

In addition to the finding that readers spend more time on a given segment when it occurrs first, the results shown in Figure 1 indicate that the relative difference in time spent on the principle and proof within a given text varies with its organization. The principle and proof reading times cannot be compared directly because the two segments vary in content. However, the difference in these reading times can be compared. Figure 1 shows that this difference was greater with the proof-first than principle-first structure. This is most likely due to differences in the spatial contiguity of the main principle statement and the restatement of the principle occuring at the end of the proof. With the proof-first structure, the principle statement followed almost immediately the final proof statement which presented the principle in different words. Thus the principle in this text was a restatement of just previously presented proof information, and not new content. Readers may have therefore "skimmed" over it. With the principle-first structure, the final proof statement is a restatement of the earlier presented principle information. However, in this case these two statements are physically separated in the text by the proof, so the principle and its restatement are not contiguous. Readers may therefore have been less likely to pass over the principle restatement, in this case the end of the proof. This would result in a smaller proof-principle difference. This suggests that there may be better learning of the principle with the principle-first structure because readers are more likely to attend to the restatement of the principle, ensuring that this information is reprocessed and thoroughly learned.

The results of this research also suggest that the principle-first structure is easier to process than the proof-first, in that it is easier for readers to determine what is important as they are reading this type of passage. There were more revisions in the sentence importance ratings for the proof-first passages, indicating that this structure is less predictable. This suggests that when the principle is presented first, it functions as a type of advance organizer so that subjects are able to determine what is important in the proof by assessing its relationship to the principle. With the proof-first structure, it is less clear

what is important in the proof because the principle (i.e., what is ultimately being proven) is unknown. This suggests that readers may be more selective in reading passages having a principle-first structure. Because they are better able to determine what is important, they may be more likely to focus on that content to the exclusion of less important information. With the proof-first structure, subjects may be more likely to distribute their attention more evenly across the text content because they are unable to determine what is important. If this is the case, then the processing difficulty imposed by the proof-first structure may result in more thorough learning of the proof overall, though not in better learning of the most critical proof content.

Finally, this research found that the proof-first structure was strongly preferred by subjects when summarizing passages. Subjects tended to reorganize proof-first passages into a principle-first structure. This finding indicates that subjects find the principle-first structure more "natural". This may be because is it a more familiar organization and follows the writing convention of placing important information first. However, it is also possible that readers use this structure in summarizing because they find it more cohesive and easier to store and recall. This suggests that subjects may reorganize passages internally according to this structure once they have finished reading.

This research has contrasted two text structures found in natural texts and applied general text learning principles in predicting comprehension differences. The findings indicate that the principle-first organization is used more often by readers in summarizing, is easier to comprehend, and focuses attention on the more important text content (i.e., the principle) when compared to the proof-first structure. These findings are consistent with current text learning research, which suggests that both providing the reader with information that can be used as a conceptual framework during reading and using a familiar organizational scheme will facilitate comprehension. However, this does not imply that the principle-first organization is preferable under all circumstances. This organization is probably

most appropriate when the instructional goal is to have the reader thoroughly learn and understand the principle, which is often the case. The proof-first organization may also be appropriate for other learning goals. This organization appears to focus more attention on the proof, and may result in more thorough learning of this content. It is not clear whether this would also produce a decrement in the learning of the principle. Ongoing research is investigating learning differences produced by these two structures. The research completed thus far suggests that consideration should be given to the learning goals associated with a given piece of text in deciding which of these two organizations would be more appropriate.
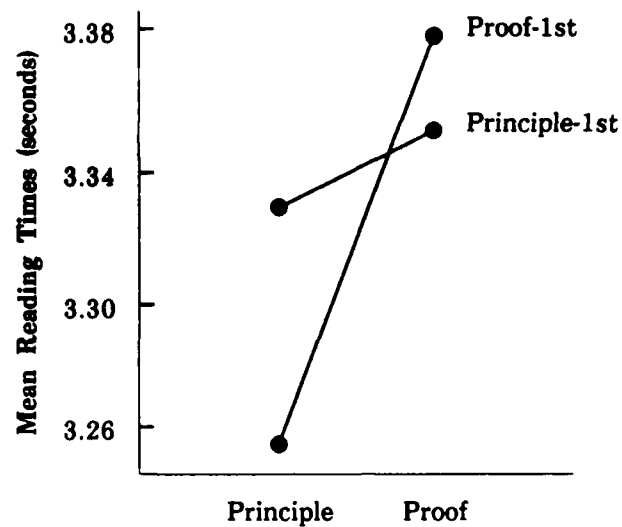
Figure 1. Estimated reading times for the principle sentences and proof sentences with each text organization.
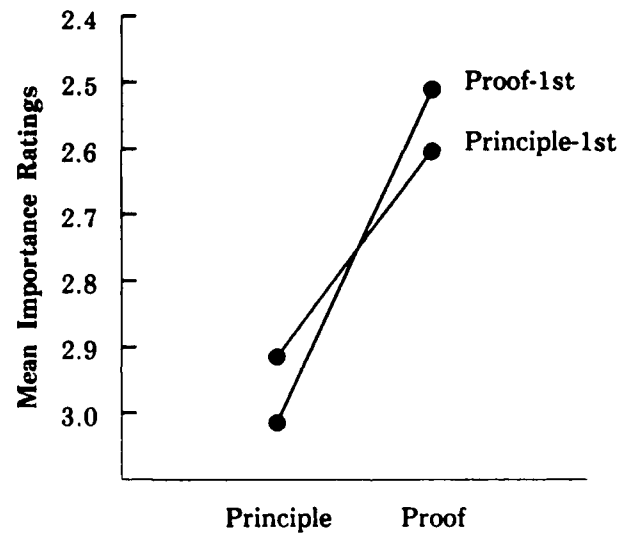

Figure 2. Mean importance ratings for the principle sentences and proof sentences with each text organization.
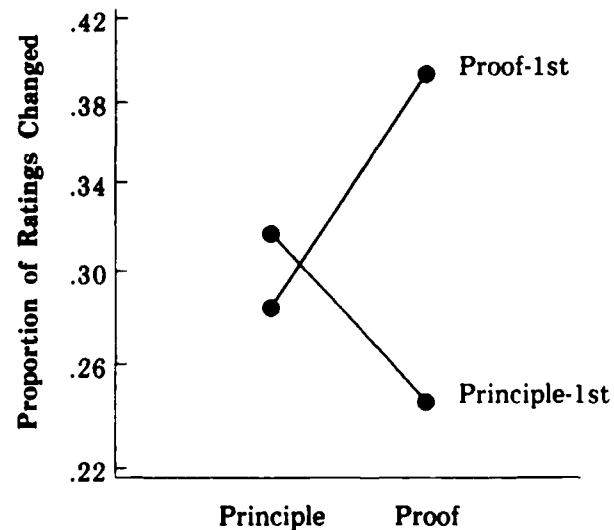

Figure 3. Mean proportion of sentence importance rating changed in the principle and proof with each text organization.